MINAR International Journal of Applied Sciences and Technology
ISSN: 2717-8234
Article type: Research Article

Received: 05/06/2022 **Accepted:** 10/07/2022 **Published:** 01/09/2022

ON iR-CONTINUOUS AND iR-CONTRA CONTINUOUS FUNCTIONS IN TOPOLOGICAL SPACE

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Abstract:

In this paper, we provide the topological space of the iR-open set. Such collections are used to define and analyze the concepts of iR-continuous and iR-contra continuous functions and some of their properties. And preservation theorems about relationships between these functions and other functions in related classes are also explored. Also, on the other hand, we give examples to show that the convers may not be true.

Keywords: iR-Open Set, iR-Cont , iR-Contra Cont.

http://dx.doi.org/10.47832/2717-8234.12.48

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Introduction:

The continuity of functions is an important and fundamental problem in general topology and other disciplines of mathematics that has been studied by numerous writers. The concept of regular continuous function was first introduced by Arya. S.P and Gupta.R.[14]. N. Leven [10] defined the semi-continuous function class in 1963. Jain [12] introduced the perfectly continuous function in 1980. Dontchev [6] coined the term contra continuity in 1996. A new weaker form of this class of function called conra semi-continuous function is introduced and investigated by Dontchev and Noiri [8], Jafari and Noiri [16,17] have introduced and investigated the concepts of contra super continuous, contra pre-continuous, and contra-continuous. function. The goal of this paper is to provide two new types of continuous functions: *iR*-Continuous and *iR*-Contra Continuous. This classes is lies strictly between the classes of regular-continuous and *i*-continuous function. We obtain several characterizations and properties of *iR*-Continuous and *iR*-contra continuous. Moreover, we investigate the relationship between these functions and other related classes of functions are also developed.

2. Preliminaries

Unless otherwise stated, (P, τ), $(K,)$, and (H,θ) denote non-empty topo-logical spaces throughout this study , no separation axioms are assumed . Let P be a space and $S \subseteq P$, $cl(S)$ and $int(S)$ will be used to represent the closure and interior of S, respectively and will be sometimes used cont. to represent the continuous and used fun. to represent the function.

Def 2.1 A subset S of a topo-logical space P is said to have been:

1- if $S = int\,(cl(S))$, regular open set [9]

2- semi-open regular [4] where there is an open set U that is regular such that $U \subset S \subset cl(U)$.

3- α-open set [11] if $S \subseteq int(cl(int(S))$.

4- *i*-open set [2] if $S \subseteq cl(S \cap U)$, when $\exists\ U \in \tau$ and $U \neq P$, $\emptyset$.

5- *ia*-open set [1] if $S \subseteq cl\,(S \cap U)$,where $\exists\ U \in aO(P)$ and $U \neq \emptyset$, P.

6- set clopen if S is both open and closed.

7- *iR*-open set [13] if $S \subseteq cl\,(S \cap U)$, where $U \in RO(P)$ and $U \neq \emptyset$, P.

The close sets of the above open sets are their equivalents. All open (resp. regular open, semi regular open set , *i*-open, clopen, *iR*-open) sets of a topo-logical space are characterized by τ (resp. $RO(P)$, $SRO(P)$, $iO(P)$, $iO(P)$, $CO(P)$, $iRO(P)$). We denote the family of all regular closed (resp. *iR*-closed) sets of topological space P by $RC(P)$ (resp. $iRC(P)$) .

The following definitions are useful in the sequel.

Def 2.2 Given a topological space P a mapping $f : P \to K$ has said to be:

1. A regular (completely) cont. [14] if the inverse image of any open set of K is a regular open set in P.

2. If the inverse image of any open subset of K is clopen set in P, it is totally (perfectly) cont. [18]

3. *RC*-cont. [5] if each open subset of K has an inverse image that is regular closed in P.

4. *i*-cont [15] if each one of open subset of K's inverse image is an *i*-open set in p.

5. if each open subset of K has an inverse image that is an *ia*-open set in P, it is *ia*-cont. [1]

6. *iR*-irresolute[13] if every *iR*-open subset of K has an inverse image that is an *iR*-open subset in P.

8. contra continuous [6] if for every open set O in K , $f^{-1}(O)$ is the closed set.

9. If an *i*-closed set in P is the inverse image of every open set of K , then *i*-contra continuous [1]

10. If an *iα*-closed set in P is an inverse image of every open subset of K , then *iα*-contra continuous [1].

11. contra-completely continuous [3] if $f^{-1}(F)$ is regular open for every closed subset F of K.

14. strongly continuous [14] if each open subset of K has an inverse image that is clopen set in P.

A following definitions and outcomes come to mind :

Def 2.3 A topological space P is said to be :

1) *iR*-T_1[13] If there exist two *iR*-open sets for each pair of distinct P points, each set including one point but not the other.

2) locally indiscrete [7] if every open set is closed.

3) If every *iR*-open set is closed, it becomes *iR*- locally indiscrete.

3) *iR*-regular if disjoint *iR*-open sets can be used to distinguish closed sets C that do not contain a point in p.

Lemma 2.4 In a topological space, all regular open set are open sets [9]

Lemma 2.5 In any topological space , every semi regular open set is an *iR*-open set [13]

Lemma 2.6 An *iR*-open set is a regular open set, regular closed set, and clopen set [13]

Lemma 2.7 In any topological space (P, τ), every *iR*-open set is an *i*-open set [13]

Lemma 2.8 In any topological space (P, τ), every *iR* -open set is an *iα*-open set [13].

3. *iR*- continuous functions

Definition 3.1 Given two topological spaces P and K, a mapping $f : P \to K$ is *iR*-cont. , if each open subset of K has an inverse image that is an *iR*-open set in P.

Exercis 3.2 P ={c, b, a, d}= K , { {a} ,{b, c, d}, ∅, P}= τ , σ = { ∅,{c},{ d}, P}. *iRO(P)* ={ ∅ , {a},{b} ,{c},{d},{b, c},{c, d},{b, d},{b, c, d}, P }

the identity function $f : P \to K$ is clearly an *iR*-cont.

Theorem 3.3 An *i*-cont. function is an *iR*-cont. function.

Proof : Allow every open subset in K to be O, and $f : P \to K$ be an *iR*-cont. function. Because f is an *iR*-cont. function , $f^{-1}(O)$ is an *iR*-open in P, and because every *iR*-open set is an *i*-open set according to lemma 2.7, $f^{-1}(O)$ is an *i*-open set in P. As a result , f is an *iR*-continuous.

Theorem 3.4 An *iα*-cont. fun. is an *iR*-cont. fun.

Proof : Let O be any open subset in K and $f : P \to K$ be an *iR*-cont. fun. Because f is an *iR*-cont. fun. in P , $f^{-1}(O)$ is an *iR*-cont. fun. in P. Furthermore, because every *iR*-open set is an *iα*-open set according to lemma 2.8, $f^{-1}(O)$ is an *iα*-open set in P. As a result , f is an *iα*-cont.

N**ote 3.5** *i*-cont. and *iα*-cont. do not require *iR*-cont., as shown in the sample below :

Sample 3.6 P={b, a, d, c}**,** K={4,3,2,1}, τ={∅ ,{a},P,{a,b},{c,d},{a,c,d}}

σ ={ ∅, {1,3},{3,4},{3},{1,3,4}, K }**,** *CO(P)* ={∅,{a,b},{c,d}, {c,d}, P } , *iRO(P)* = { ∅ , {a} , {b} , {c} , {d} , {a,b} , {c,d} , {c,b,d}, P } *iO(P)* = { ∅ , {a} ,{d},{c},{b},{a,b} ,{c,a} ,{d,a},{d,c} ,{a,b,c} ,{d,c,a}, P }. *iαO(P)* ={ ∅ , {a} , {b},{d}, {c},{a,b},{a,c} ,{a,d} ,{d,c},{b,a,c}, {a,c,d},{c,d,b}, P }. A mapping is

characterized with the values f (b)=(2) , f(a)=(1), f (d)=(4) , f (c)=(3) since $f^{-1}\{1,3\}= \{a,c\} \notin iRO(P)$. it is clear that f is an i-cont. and ia-cont. but not an iR-cont.

Theorem 3.7 An iR-cont. fun. is one that is totally cont..

Proof : Let $f : P\to K$ be a totally cont. function, and O be any open subset of Y. $f^{-1}(O)$ is clopen set in P. because f is a totallly cont. function and because any clopen set is an iR-open set according to lemma 2.6 , $f^{-1}(O)$ is an iR-open set in P. As a result , f is an iR -cont.

Theorem 3.8 An iR-cont. function is one that is completely cont..

Proof : Let O be any open subset in P and $f : P\to K$ be a completely cont. function. Because f is a completely cont. function , $f^{-1}(O)$ in P is a regular open set. Because lemma 2.6 states that every regular open set is an iR-open set, $f^{-1}(O)$ is an iR-open set in P. As a result, f is an iR- cont..

Theorem 3.9 Every iR-cont. fun. is a semi-regular cont. fun.

Proof : Take $h : P\to K$ as a semi-regular cont. fun., and V as any open subset in K. Because h is a semi-regular cont. fun., $h^{-1}(V)$ in P is a semi-regular open set. Lemma 2.5 states that each semi-regular open set is an iR-open set.

Theorem 3.10 Each RC-cont. fun. is also an iR-cont. fun.

Proof : Allow O be any open subset in K & $f : P\to K$ be an RC-cont. fun. Because f is an RC-cont. fun., $f^{-1}(O)$ in P is a regular closed set. Because lemma 2.6 states that every regular closed set is an iR-open set, $f^{-1}(O)$ is an iR-open set in P. As a result, f is an iR-cont..

Remark 3.11 This an iR-cont. function does not have to be totally cont., completely cont., or RC-cont., as demonstrated in the example below.

Example 3.12 $P = K =$\{a, b, c ,d\}, $\tau =$\{∅,\{a\},\{c, b, d\}, P\}, $\sigma =$ \{ ∅, \{b \}, P\}, $CO(P)$ = \{∅ , \{b, c, d\} \{a\}, P \}, $RO(P)$ = \{ ∅, \{a\} ,\{b, c, d\} , P\} = $SRO(P)$ = RC (P) ,$iRO(P)$ =\{∅ ,\{d\} ,\{c\},\{b\},\{a\},\{c, b\},\{c, d\},\{d, b\},\{c, b, d\}, \}. Clearly , $f : P\to K$ is an iR -continuous identity mapping, but f is not totallly continuous ,completely continuous semi regular continuous, or RC-continuous because for open subset\{ b\} , $f^{-1}(\{b\})=\{b\} \in iRO(P)$, $f^{-1}\{b\}=\{b\} \notin CO(P)$, $f^{-1}(\{b\})=\{b\}\notin RO(P) = SRO(P)= RC\ (P)$

Remark 3.13 Continuous and iR-continuous are separate notions

Example 3.14 $P= K =$ \{5 ,6, 7, 8\}, $\tau=$\{ ∅ , \{5\}, \{5,6\},\{8,7\} ,\{7, 5, 8\}, P\}

$\sigma =$\{∅, \{5\}, \{5 , 7 , 8 \}, P \} , $iRO(P)$ =\{ ∅ , \{5\}, \{6\}, \{8\},\{7\} , \{5 ,6\},\{8, 7\}, P\}. Define $f : P\to K$ as the identity mapping. f is continuous in this case, but not an iR-continuous. since $f^{-1}\{5, 7, 8\} =\{5, 7, 8\} \notin iRO(P)$

Example 3.15 $P=K=$\{d, b, c, a\},τ =\{∅ ,\{a\},\{c, b, d\}, P\},$\sigma =$\{∅ ,\{b\},\{b,c } ,P } , $iRO(P)$=\{ ∅ ,\{d\},\{b\},\{c\},\{a\},\{c, b\},\{c, d\},\{d, b\},\{d, c , b\}, P\}.

Define $f : P\to K$ as the identity mapping. In this case, f is an iR-cont. moreover, not continuously because $f^{-1}(\{b\})=\{b\}$ is not open in P.

Remark 3.16: As shown in the next example, the combination of two iR-cont. functions does not have to be iR-cont..

Example 3.17 : Let $P=K=H=$\{b, a, c\}, τ =\{∅, \{b\},\{a\},\{a,b\}, P\}, $\sigma =$\{∅ ,\{b\},\{a,c }, K \}=θ , $iRO(P)$ =\{ ∅ ,\{a\},\{b\},\{a,c\} \{b,c\}, P\} $iRO(K)$ =\{ ∅ ,\{a\},\{b\},\{a,c\} \{c\}, K\}. Define $Z : P\to K$ by Z(a)=b Z(b) =c and Z(c) =a , $g : K\to H$ as g(a) =b , g(b) =c and g(c) =a ,Then Z and g are an iR-continuous but $goZ : P\to H$ is not since $(goZ)^{-1}(b) = Z^{-1}(g^{-1}(b)) = Z^{-1}$(a)=(c) is not *an* iR -open set

Theorem 3.18 If $f : P\to K$ is an iR-cont. injection function and K is an iR-T_1 then P is an iR-T_1 .

Proof : Assume that $p , k \in P$ is such that : $p\neq k$. Because f is injective, we get $f(p)$ and $f(k) \in K$, and $f(p)\neq f(k)$. Because K is an iR-T_1, there is an iR-open set U & O in K such that $f(p)\in U$ and

$f(k) \notin U$ & $f(k) \in O$, $f(p) \notin O$. As a result, we have $p \in f^{-1}(U)$, $k \notin f^{-1}(U)$, $p \notin f^{-1}(O)$, $k \in f^{-1}(O)$, where $f^{-1}(U)$ and $f^{-1}(O)$ are *iR*-open sets , indicating that P is an *iR*-T_1.

Theorem 3.20 : If $f : P \to K$ is an *iR*-continuous and g : K→ H is an *iR*- totally continuous, then gof : $P \to H$ is *iR*-irresollute mapping.

proof : In H, let O be an *iR*-open set, if $f: P \to K$ is an *iR*-continuous and $g: K \to H$ is an *iR*-totally cont. , $f^{-1}(O)$ is clopen set in K because g is an *iR*- totally cont. $f^{-1}g^{-1}(O)$ is an *iR*-open set in P because f is an *iR*-continuous. As a result , $gof : P \to H$ is an *iR*-irresolute mapping.

Theorem 3.21 If K is an *iR*-regular, then P is an *iR*-regular if $f : P \to K$ is a continuous closed injection function.

Proof: Assume C is a closed set that does not include a point p. Because f closed, we can say that $f(C)$ is a closed set in K that does not include $f(p)$.Because K is an *iR*-regular, a disjoint *iR*-open set E and F exists,with $f(p) \in$ E and $f(C) \subset F$ respectively. implying $p \in f^{-1}(E)$ & $C \subset f^{-1}(F)$, where $f^{-1}(E)$ and $f^{-1}(F)$ are *iR*-open' sets in P since f is *iR*-continuous. Furthermore, because f is an injective, we obtain f^{-1} (E)∩ f^{-1} (F) =f^{-1} (E∩F) =$f^{-1}(\emptyset) = \emptyset$ Thus, disjoint *iR*-open sets can divide a pair of points and a closed set without a point in P.

4. *iR*-contra cont

Definition 4.1 Allow P , K be two topo-logical spaces with a map $f : P \longrightarrow K$ between them. If any open subset in K is the inverse image of an iR-closed set in P, then $f : P \to K$ is said to be *iR*-contra-continuous.

Exercising 4.2

$P=K$ ={c, b, a}, τ = {∅, {c}, {a}, { c, a}, P}. σ = {∅, {a}, {c, a}, P}. $iRO(P)$ = {∅, {b}, {a}, {a, c}, {b, c}, P } = $iRC(P)$

The identity function $f : P \to K$ is clearly an iR-contra cont.

Theorem 4.3 There is an *i*-contra cont. function for every *iR*-contra continuous fun..

Affirmation: Let O be any open subset in K and $f : P \to K$ be an *iR*-contra continuous fun.. $f^{-1}(O)$ is an *iR*-closed set in P because f is an *iR*-contra cont. fun., and because every *iR*-closed set in P is an i-closed set by [11] then $f^{-1}(O)$ is *an i*-closed set in P. Therefor f is an *i*-contra continuous ■

Theorem 4.4 Any *iR*-contra cont. function is an *iα*-contra cont..

Because every *iR*-closed set is an i-closed set[11], the **proof** is obvious.

Remark 4.5 : The example below explains that *i*-contra continuous and *iα*-contra cont. function need not be *iR*-contra continuous.

Example 4.6 In example we note f : $P \to K$ is *i*-contra continuous and *iα*-contra cont. function but not *iR*-contra cont. because for open subset {3}, f^{-1}{3}={ c} ∉ $iRO(X)$.

Theorem 4.7 An *iR*- contra cont. function is a totally cont. fun.

The following is **proof**: Let O be any open subset in K & $f : P \to K$ be a totally cont.fun.. $f^{-1}(O)$ is clopen set in P because f is a totally cont. function. Because by lemma, every clopen st is an *iR*-closed set, f^{-1} (O) is an *iR*-closed set in P. As a result , f is an *iR*-contra cont. fun.

Theorem 4.8 An *iR*-cont. function is one that is completely continuous.

Proof : Allow any open subset in K to be U, and $h: P \to K$ be a completely cont. fun., Because h is a completely cont. fun., f^{-1} (U) in P is a regular open set. Since [11] says that any regular open set is an *iR*-closed set, h^{-1} (U) is an *iR*-closed in P. As a result, f is an *iR*-contra cont.

As shown in the following example, It is not necessary for the converse of the preceding theorem to be true.

Example 4.9 $P=K=\{a, b, c, d\}$, $\tau=\{\{a\},\{b, c, d\}, P, \emptyset\}$, $\sigma=\{\emptyset, \{a,c\}, K\}$, $CO(P)=\{\emptyset, \{b, c, d\},\{a\}, P\}$, $RO(P)=\{P,\emptyset, \{a\},\{b, c, d\}$, $SRO(P)= RC(P)$, $iRO(P)=\{P,\{a\},\{b\},\{c\},\{d\},\{b, c\},\{c, d\},\{b, d\},\{b, c, d\}, \emptyset\}$.

The mapping of identities $f: P\to K$ is clearly an *iR*-contra cont., but f is not totally cont. , completely cont. or semi-regular contra cont. since for open set $\{a,c\}$, $f^{-1}\{a,c\}=\{a,c\}\in iRO(P)$, but $f^{-1}\{c,a\}=\{c,a\}\notin CO(P)$ and $f^{-1}\{c,a\}=\{c,a\}\notin RO(P)=SRO(P)$

The notions 4.9 Contra-cont. and *iR*-cont. are two separate concepts.

Example 4,11 Suppose $P=K=\{c, b, a\}$, $\tau=\{\emptyset, \{b\}, \{a\}, \{b, a\}, P\}$, $\sigma=\{\emptyset, \{c\}, \{a, c\}, K\}$, $iRC(P)=\{\emptyset, \{b\}, \{a\}, \{a, c\}\ \{c, b\}, P\}$. The identity function is defined as $I: P\to K$, I is contra continuous in this case, but not *iR*-contra-cont. because $I^{-1}(c)=c$ is not *iR*-closed.

Example 4.12 $P=K=\{a, c, b, d\}$, $\tau=\{\emptyset, \{a\},\{c, b, d\}, P\}$, $\sigma=\{\emptyset,\{b,a\}, K\}$, $iRC(P)=\{\emptyset,\{a\},\{d,a,c\},\{d,a,b\},\{c,b,a\},\{d,a\},\{b,a\},\{a,c\},\{b, c, d\}, P\}$. Define $f: P\to K$ as the identity mapping , where f is *iR*-contra cont. but not contra- cont. because $f^{-1}\{b,a\}=\{b,a\}$ is not closed.

Remark 4.13: As shown in the following example, the combination of two *iR*-contra cont. fun. Does not have to be *iR*-contra cont..

Example 4.14 Let $P=K=H=\{c, b, a\}$, $\tau=\{\emptyset, \{a\},\{b\},\{b,a\}, P\}$, $\sigma=\{\emptyset,\{b\},\{a,c\}, K\}$, $\theta=\{\emptyset,\{c\},\{a, c\}, H\}$, $iRC(P)=\{\emptyset,\{b\},\{a\},\{a,c\}\ \{b,c\}, P\}$, $iRC(K)=\{\emptyset,\{b,a\},\{b,c\},\{a,c\}, K\}$, Define $f: P\to K$ & $g: K\to H$ by $g(b)=c$, $g(a)=b$, & $g(c)=a$, $f(a)=c$, $f(b)=a$ and $f(c)=b$, Then g and f are *iR*-contra cont., but $gof: P\to H$ is not an *iR*-contra cont. because $(gof)^{-1}(c)=f^{-1}(g^{-1}(c))=f^{-1}(b)=(c)$ is not an *iR*-closed set.

Theorem4.15 contra-completely continuous are *iR*-contra continuous functions.

Proof :. Any closed set in K is denoted by the letter D. Since f is contra completely cont. function then $f^{-1}(D)$ is regular open set in P. Since , every regular open set is *an iR*-closed set lemma 2.4 then , $f^{-1}(D)$ is an *iR*-closed set in P.Thus , f is an *iR*-contra-continuous ■

Theorem 4.16 Take $f: (P, \tau)\to (K,\sigma)$ to be a function, then

i) f is contra continuous if f is *iR*-cont. and P is an *iR*-Locally indiscrete.

Proof : Assume that f is *iR*-cont. , that P is *iR*-Locally indiscrete, and that O is open in K. $f^{-1}(O)$ is an *iR*-open in P because f is an *iR*-cont. function and because P is *iR*-Locally indiscrete, using definition 2.3 (iii), $f^{-1}(O)$ is a closed set in P, f is contra continuous according to definition 2.2. (viii).

ii) f is *iR*-contra cont. if f is an *iR*-cont. and K is Locally indiscrete.

Proof: Assume that f is *iR*-cont. , that K is locally indiscrete, and that O is an open subset in K because K is locally indiscrete, $f^{-1}(O)$ is a closed set in K using definition 2.3(ii). $f^{-1}(O)$ is an *iR*-closed in P because f is an *iR*-cont. function. As a result, 3.1 f is *iR*-contra cont. by definition.

Theorem 4.17 : If $f: (P, \tau)\to (K,\sigma)$ is an *iR*-contra continuous fun. and $g: (K,\sigma)\to (H,\theta)$ cont. fun. ,then $gof: P\to H$ is an *iR*-contra cont. fun..

Certainty: Because g is continuous, O is open in H , and $g^{-1}(O)$ is open in K , because f is *iR*-contra continuous. $f^{-1}g^{-1}(O)$ is an *iR*-closed set in P , hence $(gof)^{-1}(O)$ is also an *iR*-closed set in P. So, gof is *iR*-contra continuous ■

Theorem 4.18: If $f: (P,\tau)\to (K,\sigma)$ is an *iR*-continuous fun. and $g: (K,\sigma)\to (H,\theta)$ is a perfectly continuous fun., then $gof: P\to H$ is an *iR*-contra continuous fun..

Proof: Since g is perfectly cont., let O be open set in H . $g^{-1}(O)$ is clopen in K.. because f is iR-contra cont. , $f^{-1}g^{-1}$ (O) is an iR-closed set in P, hence $(gof)^{-1}(O)$ is an iR-closed set in P, i.e. gof is an iR-contra cont.

Conclusion

Through the study carried out by Iskandar, Muhammad and Khattab about the open set of type i. We arrive at the following definition : The subset S from the topological space (P, τ) is said to be iR-open set if $S \subseteq Cl\,(S \cap U)$, where $U \in RO(P)$. In this paper , This class of set used to define and study the concept of iR- continuous application, iR-contra continuous application. We are investigating some of the characteristics of this application. The relationships between these applications and other related classes of applications is also under development. We were able to introduce the continuous application type-iR along with other types of continuous applications and compare them using this definition. And we found that there is a close correlation between these application and regular continuous application , semi-regular continuous application , i- continuous application , ia- continuous application and totally continuous application. transferring this correlation to the contra- continuous applications of these types of open set.

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